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Design of Integrated Double Buck Boost Converter for Industrial Applications

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ABSTRACT: An Integrated double buck boost converter is analyzed and the design methodology is made as a high power factor of the power supply for the power LED lamps. - The IDBB converter features just one controlled switch and two inductors and is able to supply a solid-state lamp from the mains, providing high power factor. Here with a careful design of the converter, the filter capacitances can be made small enough so that film capacitors may be used in this way, the converter mean time between failures can be made high. The operation of the converter is equivalent to two buck–boost converters in cascade, in which the controlled switch is shared by the two stages. Compared to Buck boost converter this IDBB will provide high input power factor, reduced ripple current. Thus, the proposed converter includes two inductors, two capacitors, three diodes, and one ground-referenced controlled switch, featuring affordable low cost and good reliability for this kind of applications.

KEYWORDS: single stage, double buck-boost, power factor, ripples current.

I.INTRODUCTION

A DC-DC power converters have a wide range of uses today and are becoming increasingly more important in every day use. DC power supplies are probably the largest use of the converters and are much more compact and efficient than the old method of conversion with transformers. These converters can have an output of any range; for instance, one can run logic gates or large dc motor drives with a simple converter. Electronic switch-mode DC to DC converters convert one DC voltage level to another, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. By adjusting the duty cycle of the charging voltage (that is, the ratio of on/off time), the amount of power transferred can be controlled. Usually, the duty cycle will be applied to control the output voltage, though it could be applied to control the input current, the output current, or maintain a constant power. In general, the term "DC-to-DC converter" refers to one of these switching converters these converters are also used for electronic isolation and power factor correction. The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. Here the output voltage is of opposite polarity as the input where the output voltage is adjustable based on the duty cycle of the switching transistor. Here an Integrated double buck boost converter is used which will provide a non inverting output as that of buck boost converter to supply power-LED lamps from the ac mains providing high power factor (PF), low LED current ripple and high efficiency.

II.BLOCK DIAGRAM

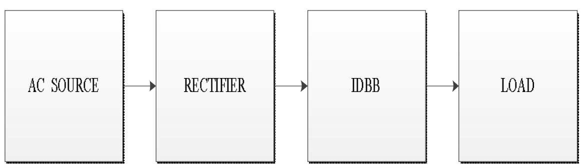

Fig. 1 Block diagram of the proposed system

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Fig .1 shows the overall block diagram of the project. The integrated double buck boost converter is fed using an ac source with rectifier. The output of the IDBB is fed to the LED load.

III. INTEGRATED DOUBLE BUCK BOOST CONVERTER

Integrated double buck–boost (IDBB) converter is used as a high-power-factor offline power supply for power-LED lamps. The IDBB converter features just one controlled switch and two inductors and is able to supply a solid-state lamp from the mains, providing high power factor and good efficiency. Here the IDBB converter is analysed and a design methodology is simulated. Here the filter capacitances can be made small enough so that film capacitors may be used. In this way, the converter mean time between failures can be made high. The operation of the converter is equivalent to two buck–boost converters in cascade, in which the control switch is shared by the two stages

1. Circuit and Operation

The converter behaves as two buck–boost converters in cascade. The input buck–boost converter is made up by L_i, D_1, C_B and M_1, and the output buck–boost converter comprises L_0, D_2, D_3, C_0,and M_1. The reversing polarity produced by the first converter in the capacitor C_B is corrected by the second converter, given a positive output voltage with respect to ground. The bus capacitor can also be made low enough to be implemented with film technology, thus avoiding the low-life-rating electrolytic capacitors in the whole converter. This implies the design of the converter so that it operates with a duty cycle lower than 0.5.The circuit diagram is as shown in Figure 2. The IDBB input inductor operates in the continuous conduction mode and the output inductor operates in the discontinuous conduction mode. The inductor operating in the continuous conduction mode will increase the power factor in the input side, while the output side inductor will reduce the ripple current values.

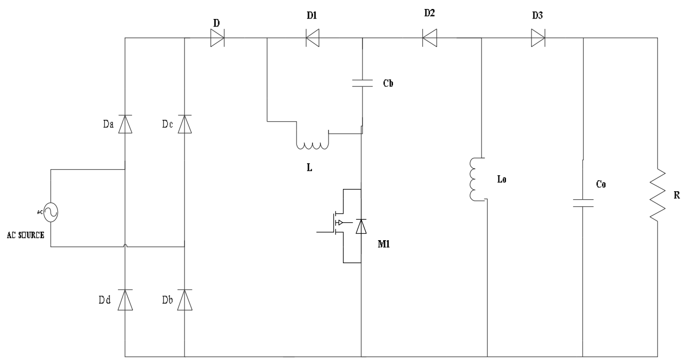

Fig.2 Circuit diagram of a Integrated double buck boost converter

2. Discontinuous Conduction Mode (DCM)

By operating the input inductor in discontinuous conduction mode (DCM), the average current through the line will be proportional to the line voltage, therefore providing a near unity PF. The operation in DCM has the advantage of providing a bus voltage independent of the duty cycle and output power. However, it presents the disadvantage of requiring a higher value of the output capacitance to achieve low current ripple through the load it must be noted that the input stage must be operated in DCM under any load and input voltage conditions to assure high input power factor. The duty cycle limit D can be obtained from the voltage conversion ratio in the DCM–CCM boundary .As long as the actual duty cycle is lower than the limit value given by the equation (1), the input stage will operate in DCM.

$$D_{limit} = \frac{1}{1+\frac{V_g}{V_B}} \qquad (1)$$

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3. **C**ontinuous Conduction Mode **(CCM)**

In order to have a reduced value for the output capacitance, the output inductance is operated in CCM, because the current ripple is lower in this operation mode. In addition, the operation of the second stage in CCM with a duty cycle lower than 0.5 reduces the low-frequency ripple voltage since it is multiplied by the buck–boost converter voltage ratio. In this way, it will be possible to use a film capacitor to implement the output capacitance, thus having a higher life rating and better efficiency than using electrolytic capacitor at the output stage in CCM, the bus and output voltages are reversely dependent on the duty cycle. Since the output stage corresponds to a buck–boost converter operating in CCM, the bus voltage V can be calculated by using the voltage conversion ratio for this converter. For example, if the duty cycle increases, the output voltage increases and the bus voltage decreases in the same amount. The sum of both voltages does not depend on the duty cycle, being only proportional to the line peak voltage, as given by the following equation (2).

$$V_B + V_O = \frac{V_g}{2\sqrt{k}} \qquad (2)$$

IV.OPERATION OF IDBB

IDBB operation consists of three stages which are explained as shown in following three modes. In the mode I operation the circuit will have the current path as shown in the following Figure 4.2. Here in the mode I operation the switch will be closed and the current flow path will be as shown in the following Figure 3.

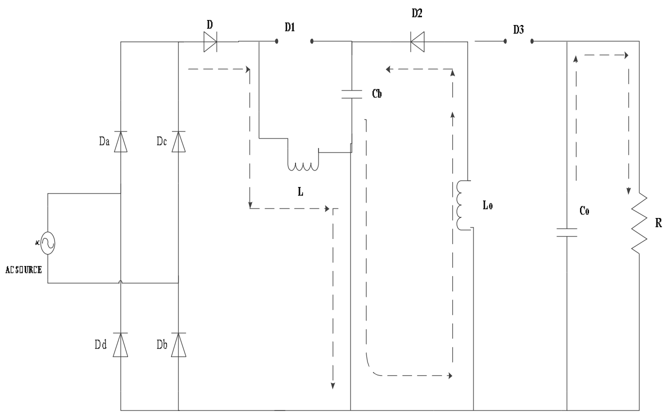

Fig.3 Circuit diagram of MODE I operation of IDBB

The current flow path will be in the path of the input side inductor and the switch M diode D1 will be in the reverse biased and will not be in the conduction state. The diode D3 will be in the blocking state. The output side inductor will be operated in the CCM mode.

In the mode II operation the circuit will have the current path as shown in the following Figure 4.

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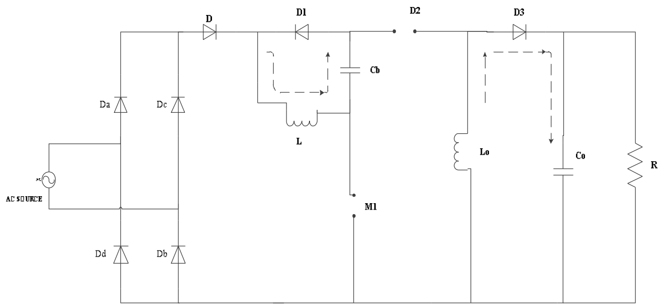

Fig.4 Circuit diagram of MODE II operation of IDBB

Here the switch M1 will be in the open state and the current flow path will be through L_i and the diode D1 will be in the conduction state and in this mode the output side inductor L_0, D_3, C_0 will be in the conduction state and the inductor L_0 will be in the continuous conduction state. The CCM state of the output side inductor will ensure the reduced ripple current in the output side

In the mode III operation the circuit will have the current path as shown in the following Figure 5.

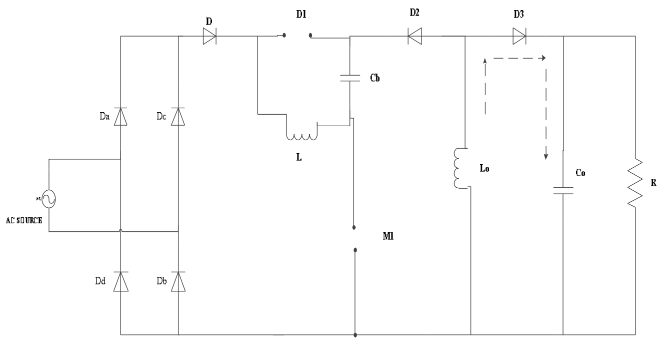

Fig.5 Circuit diagram of MODE III operation of IDBB

V. REACTIVE COMPONENTS

The input inductance L_i can be calculated by using the formula by assuming 100% efficiency

$$L_i = \frac{D^2 V_g^2}{4 P_0 f_s} \qquad (3)$$

The bus capacitor C_B is calculated to limit the low-frequency ripple of the bus voltage, which is the voltage applied to the second stage

$$C_B = \frac{D^2 V_g^2}{8\pi V_B L_i \Delta V_{B\_LF} f_s f_l} \qquad (4)$$

The output inductance L_0 and capacitance C_0 are obtained using the well-known expressions for a buck–boost converter operating in CCM

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$$L_0 = \frac{\Delta V_B}{0.5 \Delta I_{L0\_HF} f_s} \qquad (5)$$

$$C_0 = \frac{\Delta I_0}{\Delta V_{0\_HF} f_s} \qquad (6)$$

VI .POWER LED'S

A light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices and are increasingly used for other lighting. Appearing as practical electronic components in 1962, early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet and infrared wavelengths, with very high brightness.

1. Electroluminescence

When a light-emitting diode is forward-biased (switched on) electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence and the colour of the light (corresponding to the energy of the photon) is determined by the energy gap of the semiconductor. An LED is often small in area (less than 1 mm^2) and integrated optical components may be used to shape its radiation pattern.

LED's present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching. LED powerful enough for room lighting are relatively expensive and require more precise current and heat management than compact fluorescent lamp sources of comparable output. General-purpose lighting needs white light. LED emit light in a very small band of wavelengths, emitting light of a colour characteristic of the energy band gap of the semiconductor material used to make the LED.

To emit white light from LED requires mixing light from red, green, and blue LED, or using a phosphor to convert some of the light to other colours. The first method (RGB- or dichromatic white LED's) uses multiple LED chips, each emitting a different wavelength, in close proximity to generate the broad spectrum of white light. The advantage of this method is that the intensity of each LED can be adjusted to "tune" the character of the light emitted. The major disadvantage is high production cost. The character of the light can be changed dynamically by adjusting the power supplied to the different LED.

2. Series resistance calculation

The formula to calculate the correct resistance to use is

$$R = \frac{(E_S - E_{LED})}{I_{LED}} \qquad (7)$$

E_S = Source voltage
R= Resistance
E_{LED} = Voltage drop across the LED
I_{LED}= Current drop across the LED

Where power supply voltage (E_s) is the voltage of the power supply, e.g. a 9 volt battery, LED voltage drop (E_{LED}) is the forward voltage drop across the LED, and LED current (I) is the desired current of the LED. The above formula

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requires the current in amperes, although this value is usually given by the manufacturer in mill amperes, such as 20 mA. Typically, a LED forward voltage is about 1.8–3.3 volts; it varies by the colour of the LED. A red LED typically drops 1.8 volts, but voltage drop normally rises as the light frequency increases, so a blue LED may drop around 3.3 volts.

Table .1 Comparisons between conventional and proposed converter

Conventional Buck Boost Converter	IDBB
output will be inverted polarity	Non inverting output polarity
Ripple current value 1A	Ripple current value 0.05A
Power factor value 0.6	Power factor value 0.9

VII.SIMULATION RESULTS

The buck boost and the proposed integrated double buck boost converter was simulated using MATLAB/PSIM software tool under different duty cycle and performance analysis had been made. The integrated double buck boost converter will produce the non inverting output as compared with the conventional buck boost converter where the voltage will be inverted. When the duty cycle is varied the output voltage will vary as the buck or boost based upon the duty cycle value by choosing the value above 0.5 or below 0.5 by controlling the duty cycle the output voltage value will vary.

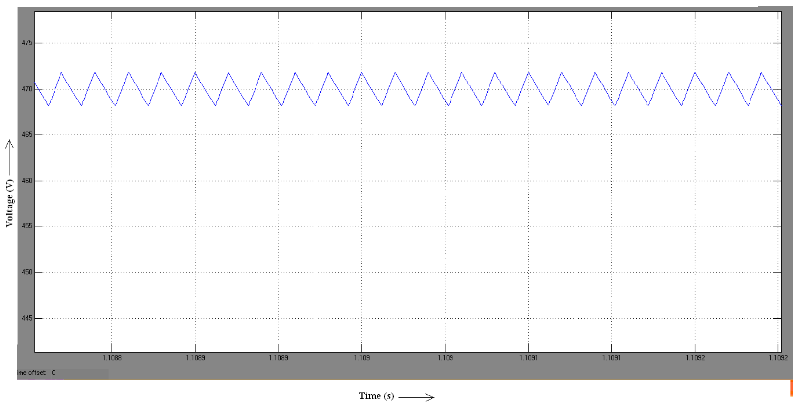

Fig.6 IDBB output voltage

The output current value of the integrated double buck boost converter is as shown in the Figure 6. The output side current will be in the continuous conduction mode. Compared with the conventional buck boost converter the integrated buck boost converter will be having the reduced ripple current value which is in the value of 0.05A which is greatly reduced compared with the conventional buck boost converter the value of the current will also be controlled through the duty cycle value.

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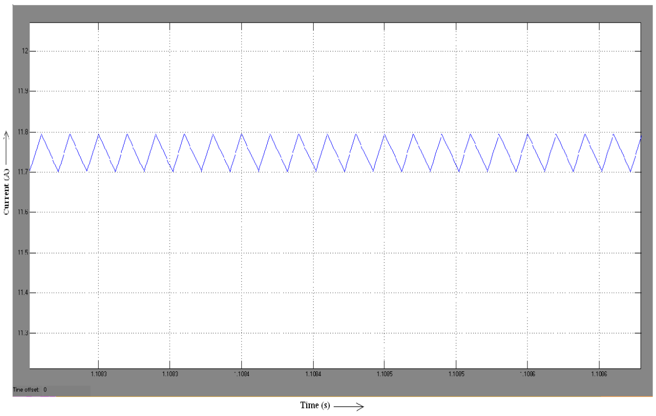

Fig.7 IDBB output current waveform

The power factor measurement of the integrated double buck boost converter is as shown in the Figure 7. The integrated double buck boost converter will have the supply side power factor as shown in the Figure 6.13. The power factor value will vary from 0.85 to 1 and the average value of the power factor will be as 0.9 also the power factor value when compared with the conventional buck boost converter will be high.

Integrated double buck boost converter when operated with the 60% duty cycle will have the output voltage as shown in the above Figure 6.14 since the duty cycle value is increased to 0.6 the output voltage is increased as the circuit is operating in the boost mode increasing the voltage to nearly 600V. With the further increasing of duty cycle the output voltage can be increased.

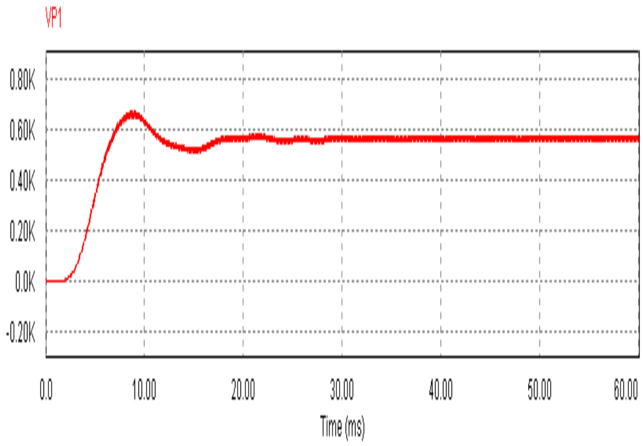

Fig.8 IDBB with 60% duty cycle

VIII. CONCLUSION

The integrated double buck boost converter provides major advantages over the other types of the conventional buck boost converter such as the improved power factor, non inverted output voltage as compared with the conventional converters, reduced ripple current in the output side. In this converter has the added advantage as that of the other converter as that this will provide the reduced ripple current, in the output side which reduces the junction temperature so that the LED's which are used in many applications will have the increased life time with improved efficiency. The IDBB has the input side power factor of 0.9 which is high compared with the conventional buck boost converter comparison as shown above the table.

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